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**Oyobe et al.**

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(54) **VEHICLE INCLUDING MOTOR CONTROL DEVICE, AND CONTROL METHOD FOR VEHICLE**

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See application file for complete search history.

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(57) **ABSTRACT**

A vehicle, including a motor having a rotor, a resolver that detects a rotation angle of the rotor and a control device, and a control method for the vehicle are provided. The control device executes rectangular-wave control over the motor using the rotation angle of the rotor, detected by the resolver, executes zero learning for learning a deviation between an origin of an actual rotation angle of the rotor and an origin of the detected rotation angle of the rotor, corrects the detected rotation angle of the rotor on the basis of a result of the zero learning, and, when the zero learning has not been completed yet, executes avoidance control for avoiding a rapid variation in output of the motor.

**16 Claims, 12 Drawing Sheets**

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**H02P 6/14** (2006.01)  
**H02P 6/08** (2006.01)  
**H02P 21/00** (2006.01)

(52) **U.S. Cl.**  
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**H02P 21/0025** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H02P 6/142

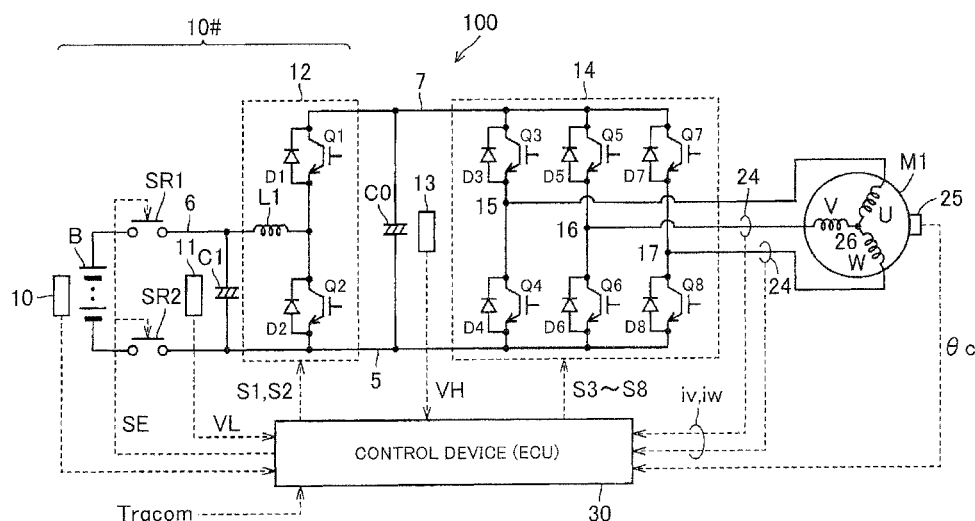


FIG. 1

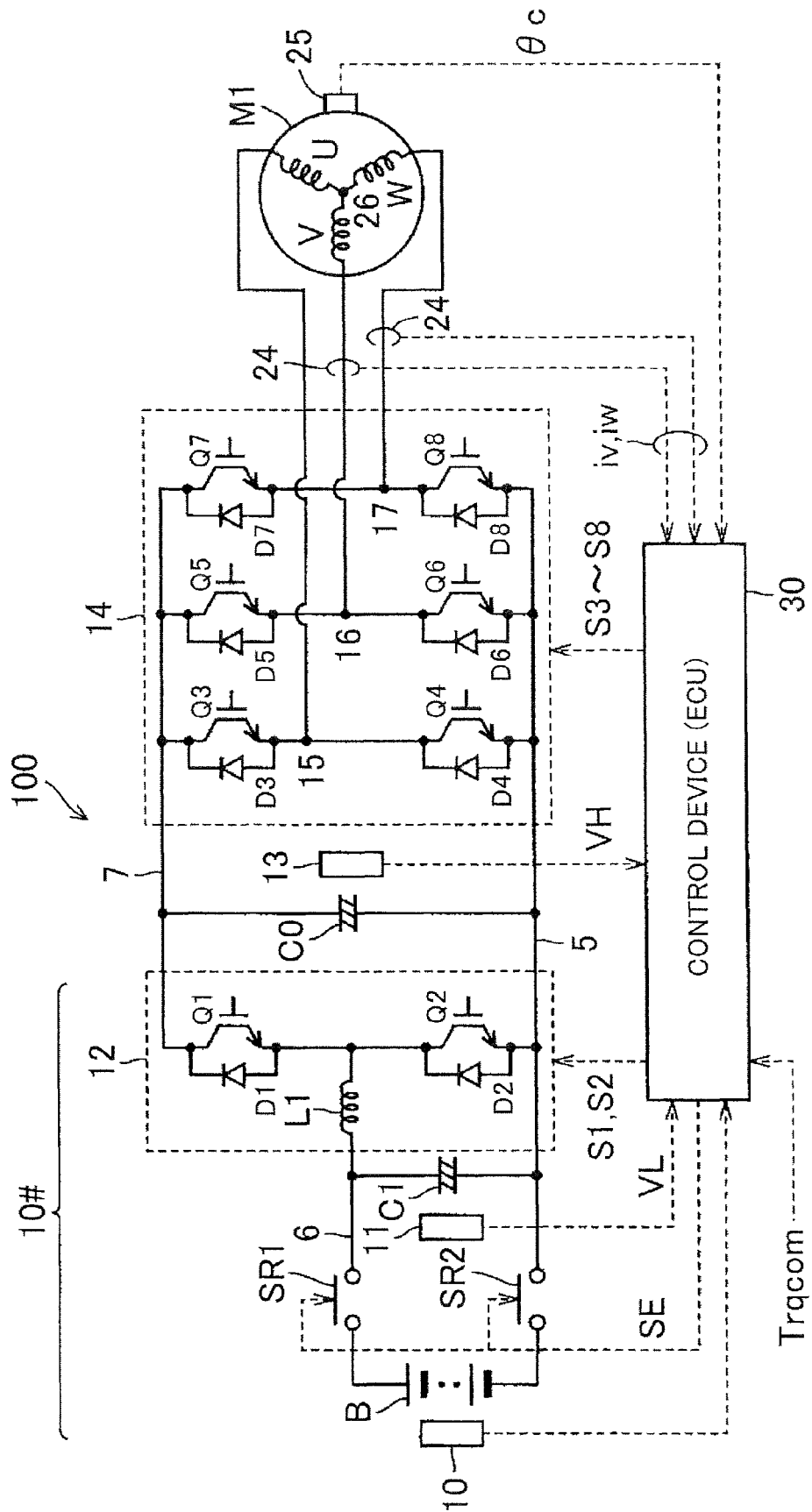


FIG. 2




CONTROL	PWM CONTROL MODE		RECTANGULAR-WAVE VOLTAGE CONTROL MODE
	SINUSOIDAL PWM	OVER-MODULATION PWM	RECTANGULAR WAVE (ONE PULSE)
OUTPUT VOLTAGE WAVEFORM OF INVERTER	FUNDAMENTAL -WAVE COMPONENT 	FUNDAMENTAL -WAVE COMPONENT 	FUNDAMENTAL -WAVE COMPONENT 
MODULATION FACTOR	0~0.61	0.61~0.78	0.78
CHARACTERISTIC	SMALL TORQUE FLUCTUATIONS	IMPROVEMENT OF OUTPUT IN INTERMEDIATE -SPEED RANGE	IMPROVEMENT OF OUTPUT IN HIGH-SPEED RANGE

FIG. 3

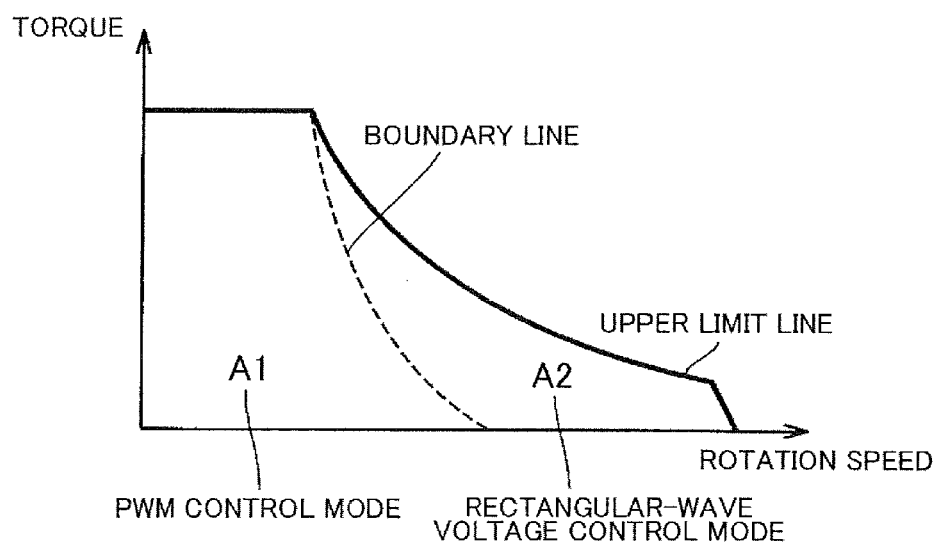


FIG. 4.

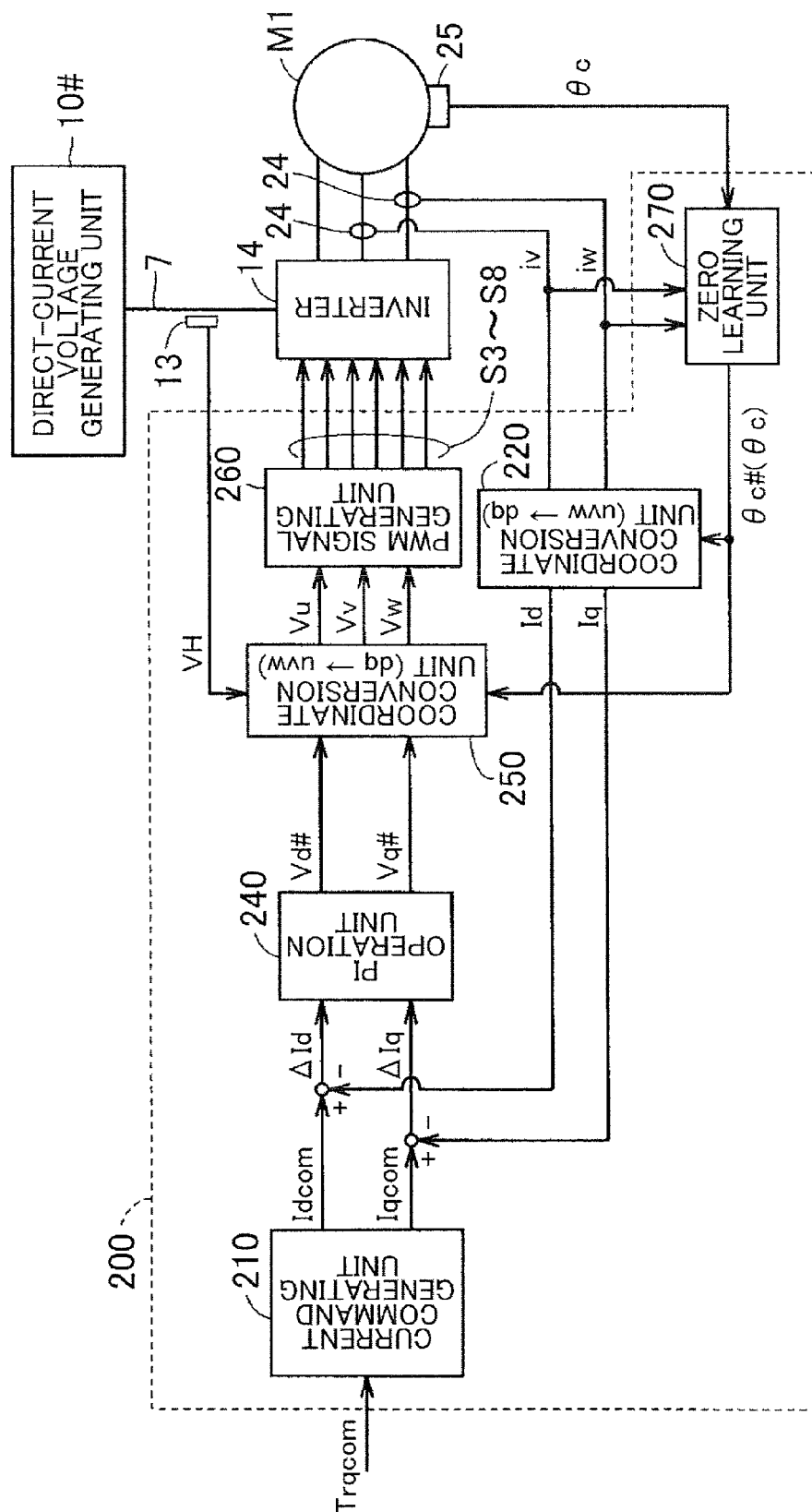


FIG. 5

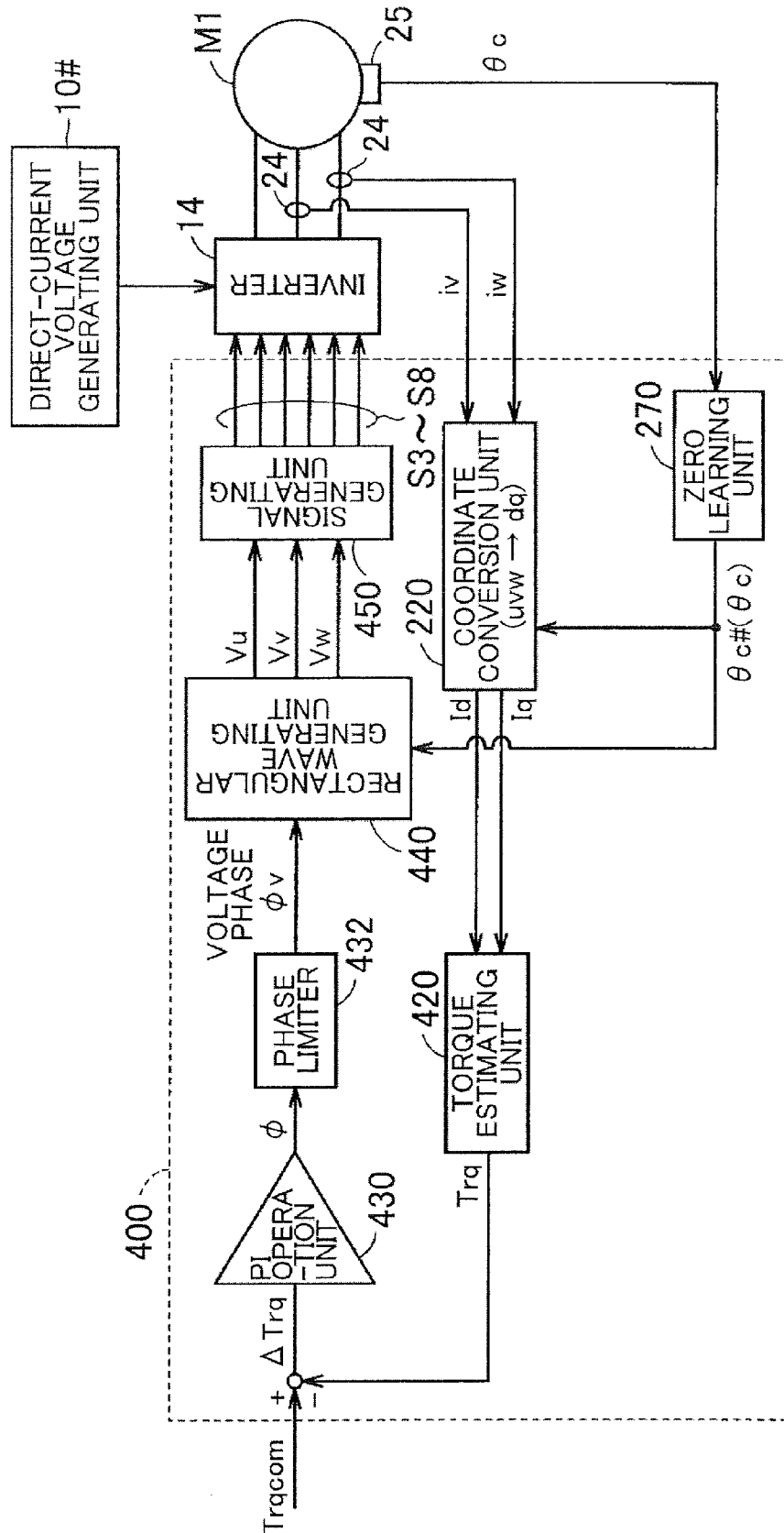


FIG. 6

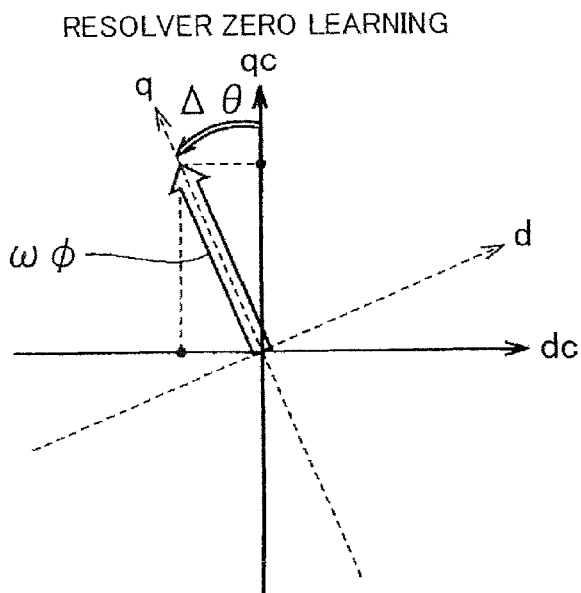


FIG. 7

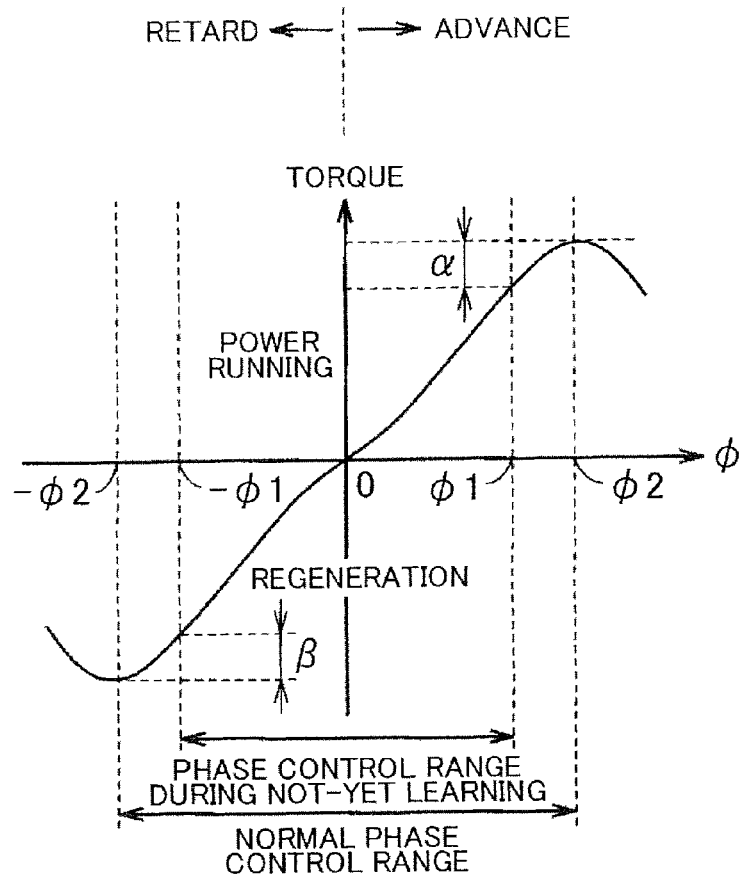


FIG. 8

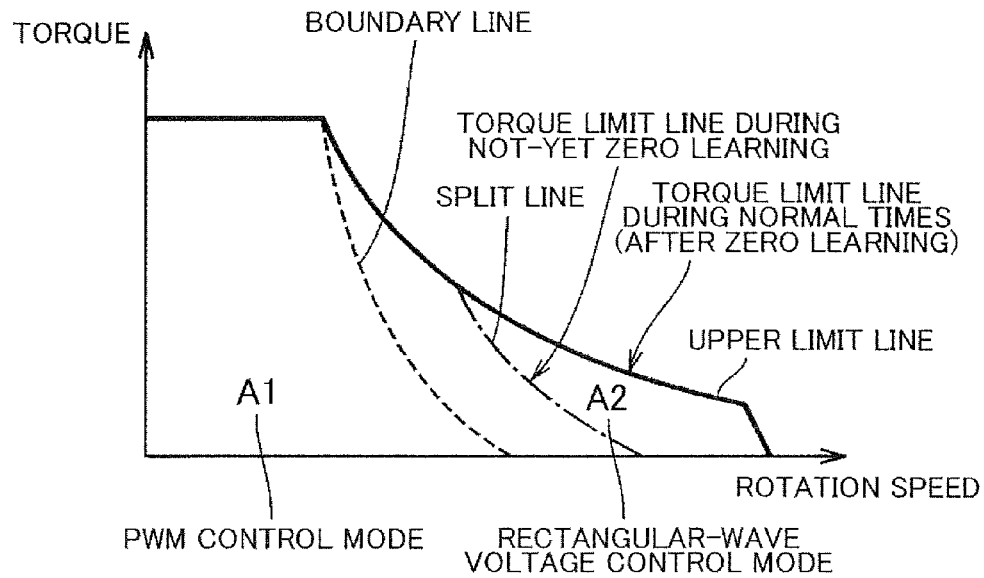


FIG. 9

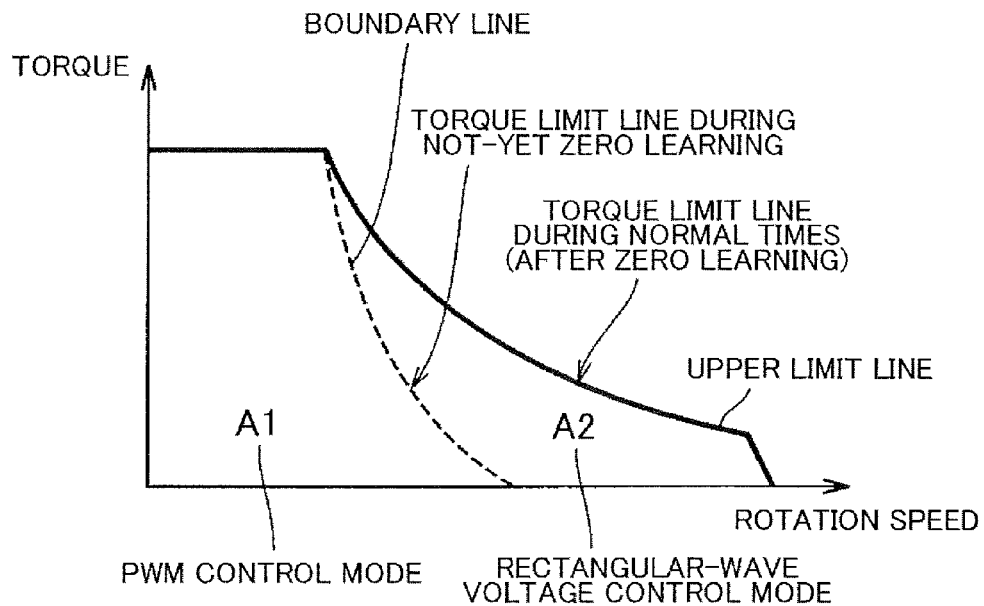


FIG. 10

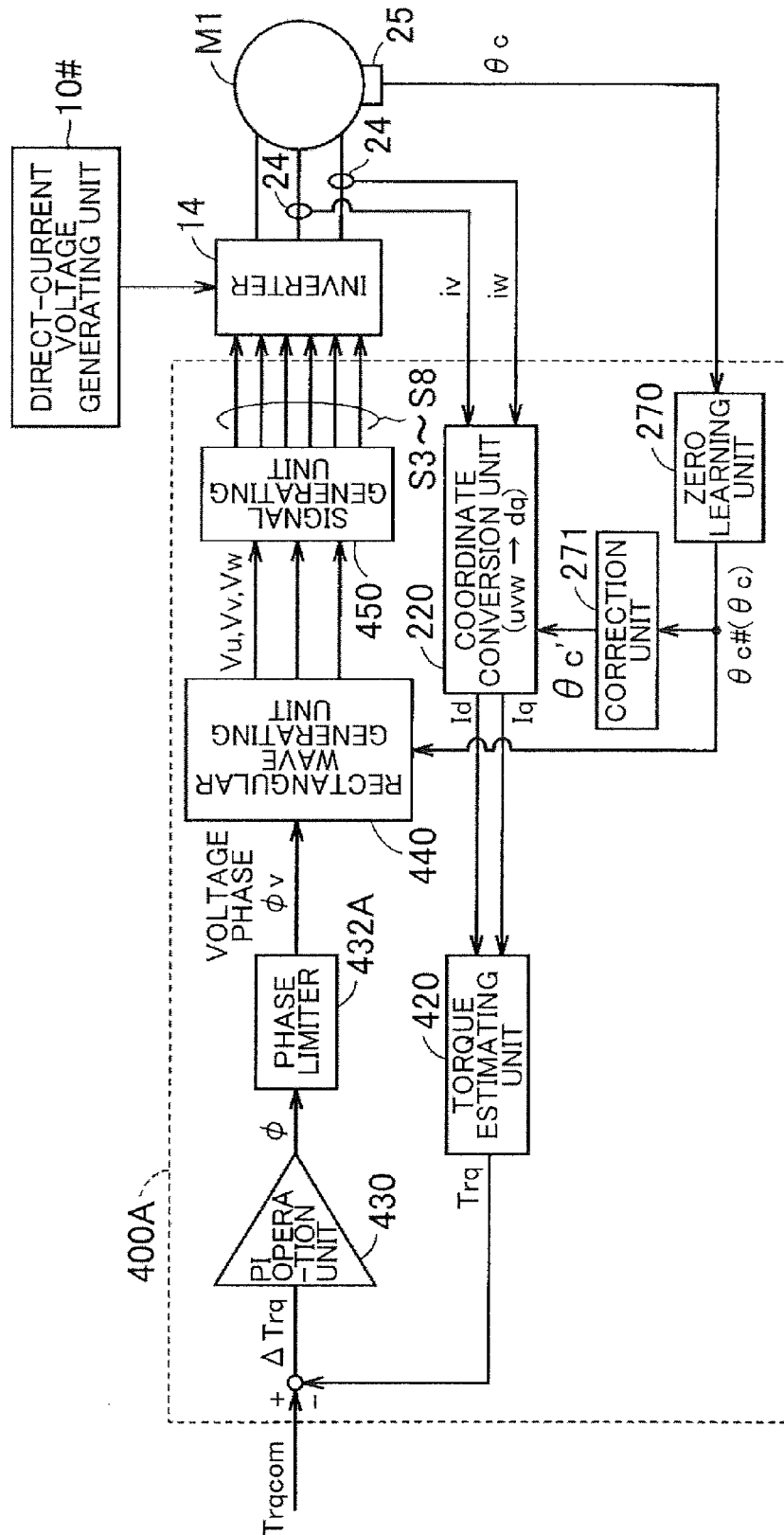




FIG. 11

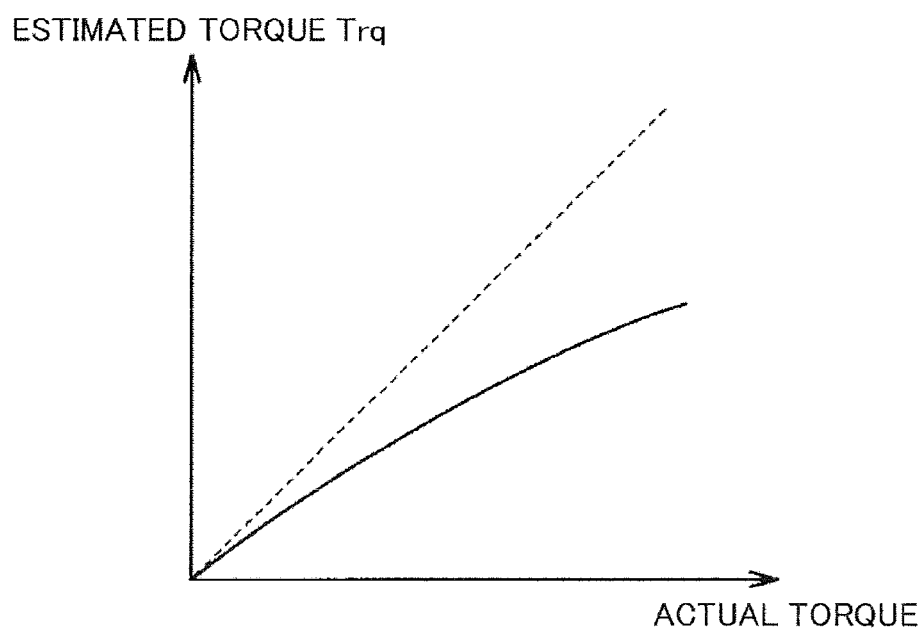


FIG. 12

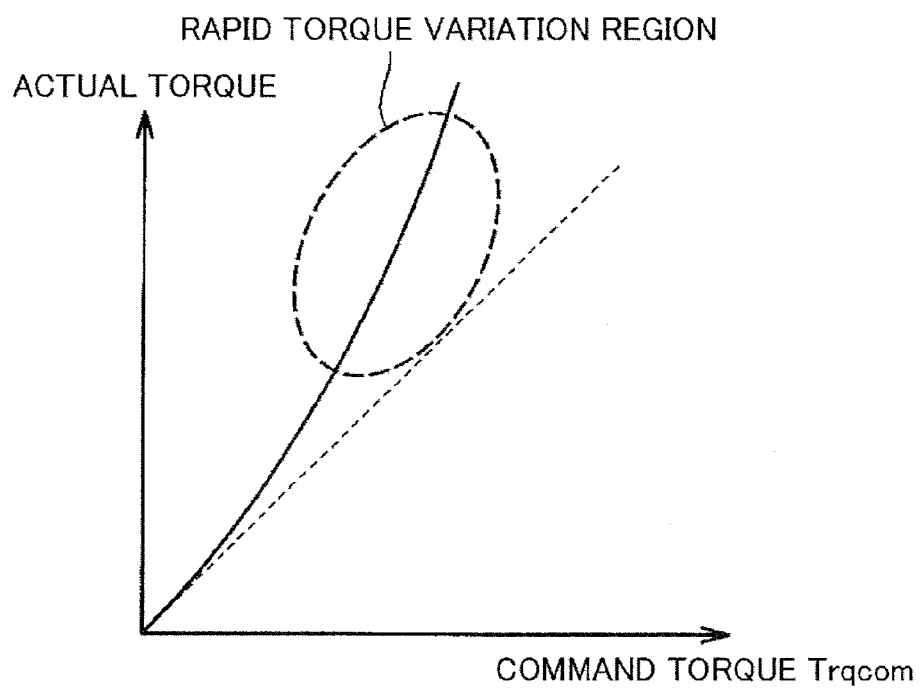


FIG. 13

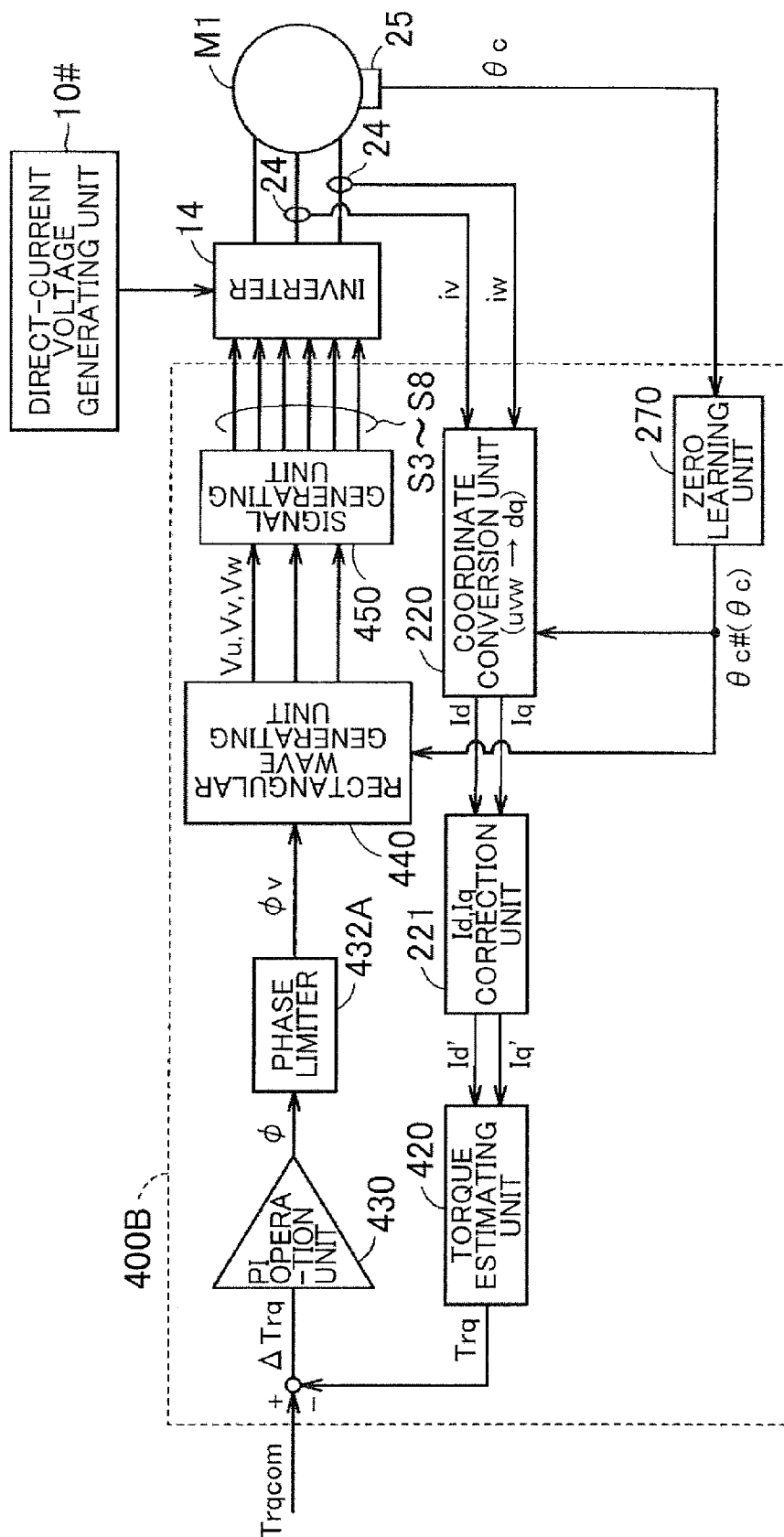


FIG. 14

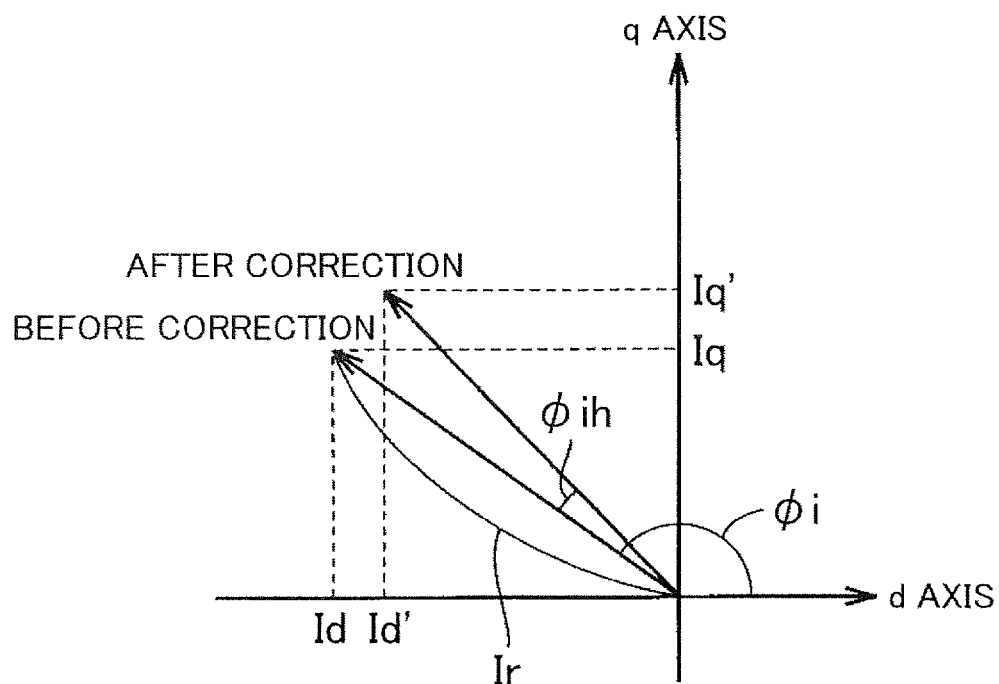


FIG. 15

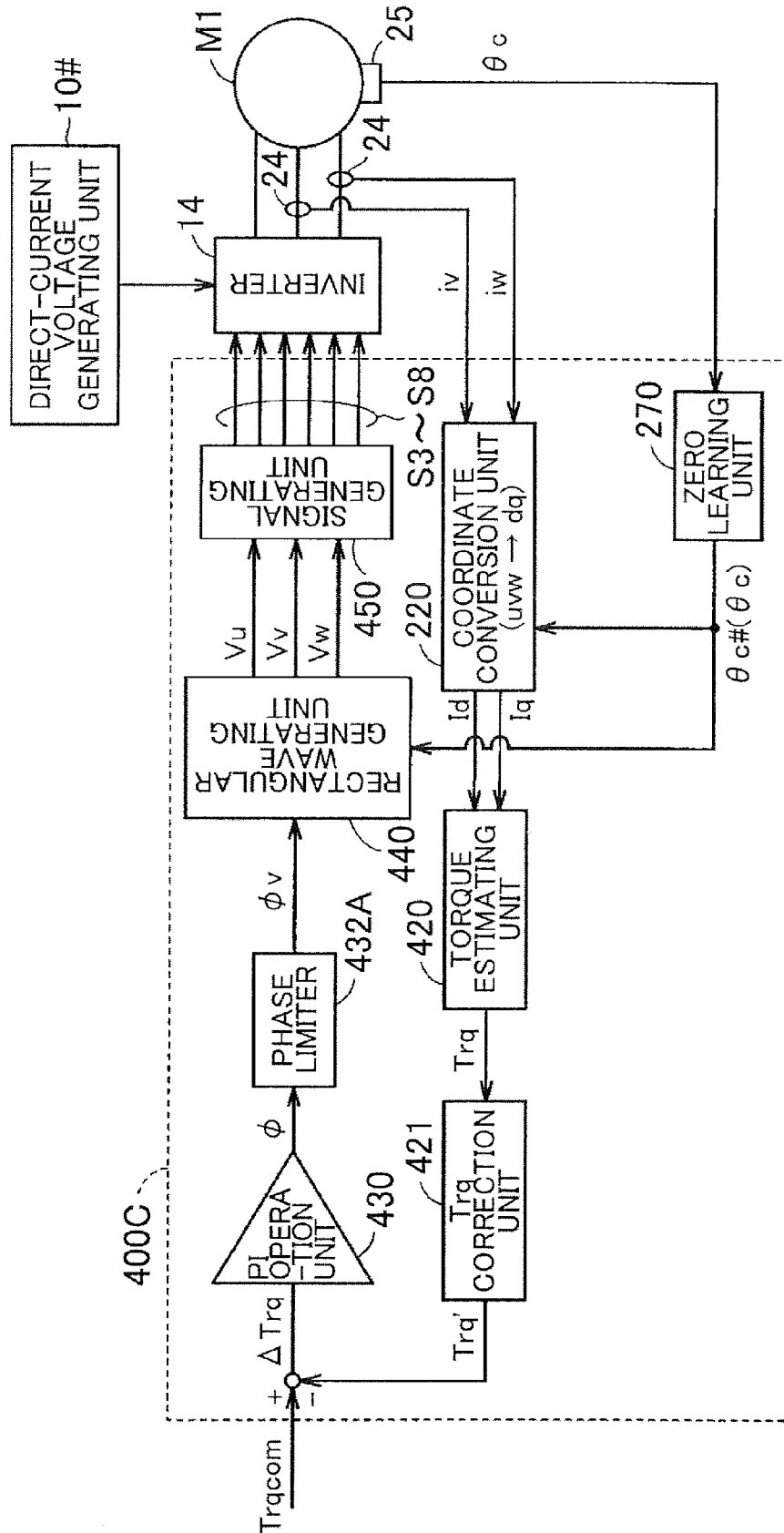
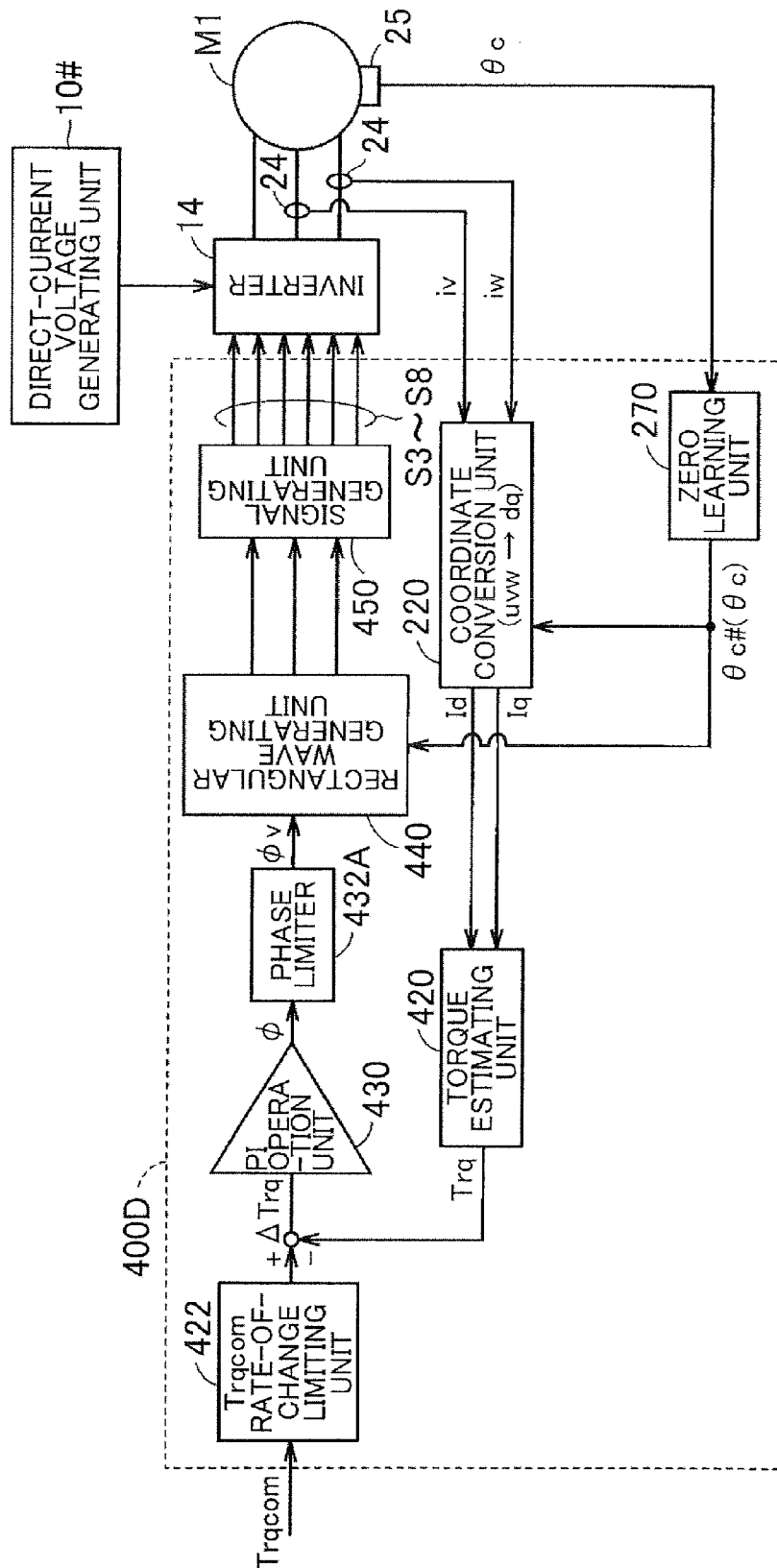


FIG. 16



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# VEHICLE INCLUDING MOTOR CONTROL DEVICE, AND CONTROL METHOD FOR VEHICLE

## INCORPORATION BY REFERENCE

The disclosure of Japanese Patent Application No. 2012-188580 filed on Aug. 29, 2012 including the specification, drawings and abstract is incorporated herein by reference in its entirety.

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The invention relates to a vehicle including a control device that executes rectangular-wave control (rectangular-wave voltage control) over a motor using an output of a resolver, and a control method for the vehicle.

### 2. Description of Related Art

Japanese Patent Application Publication No. 2008-283751 (JP 2008-283751 A) describes a technique for, in a system that drives a motor in a rectangular-wave control mode, preventing disturbing torque fluctuations by computing a motor command current vector and a motor detected current vector for torque control on the basis of a rotor rotation position detected by a rotor rotation position sensor and then correcting the phase of a rectangular-wave voltage such that a deviation between an estimated torque obtained from the motor command current vector and an estimated torque obtained from the motor detected current vector becomes zero.

Incidentally, a sensor called resolver is generally used for the sensor that detects a rotor rotation position, and a detected value of the resolver may include a so-called zero offset error. Therefore, it is desirable that control for calculating the zero offset error (hereinafter, also referred to as “zero learning”) be executed and then the detected value of the resolver be corrected on the basis of the result. However, if zero learning has not been completed, there is a concern that an error arises in estimated torque due to the influence of the zero offset error and, as a result, the output torque of the motor rapidly varies.

## SUMMARY OF THE INVENTION

The invention provides a vehicle that executes rectangular-wave control over a motor using an output of a resolver and that includes a control device configured to execute control for avoiding a rapid variation in output torque of the motor even during not-yet zero learning, and a control method for the vehicle.

An aspect of the invention provides a vehicle including: a motor having a rotor; a resolver configured to detect a rotation angle of the rotor; and a control device. The control device is configured to execute rectangular-wave control over the motor using the rotation angle of the rotor, the rotation angle being detected by the resolver. The control device is configured to execute zero learning for learning a deviation between an origin of an actual rotation angle of the rotor and an origin of the detected rotation angle of the rotor, and correct the detected rotation angle of the rotor on the basis of a result of the zero learning. The control device is configured to execute avoidance control for avoiding a rapid variation in output of the motor when the zero learning has not been completed yet.

Another aspect of the invention provides a control method for a vehicle including: a motor having a rotor and a resolver configured to detect a rotation angle of the rotor. The control method includes: detecting the rotation angle of the rotor with the use of the resolver; executing rectangular-wave control

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over the motor using the detected rotation angle; executing zero learning for learning a deviation between an origin of an actual rotation angle of the rotor and an origin of the detected rotation angle of the rotor; correcting the detected rotation angle of the rotor on the basis of a result of the zero learning; and executing avoidance control for avoiding a rapid variation in output of the motor when the zero learning has not been completed yet.

In the vehicle and the control method therefor, a control range of a rectangular-wave voltage phase that is used in the rectangular-wave control may be set to a first range after the zero learning has been completed. The avoidance control may be control for limiting the control range of the rectangular-wave voltage phase as compared to the first range.

In the vehicle and the control method therefor, when the rectangular-wave control is executed, an estimated torque of the motor may be calculated using the detected rotation angle of the rotor and then feedback control may be executed over the motor on the basis of a deviation between the estimated torque and a command torque of the motor. An upper limit of the command torque during the rectangular-wave control may be set to a first line after the zero learning has been completed. The avoidance control may be control for decreasing the upper limit of the command torque during the rectangular-wave control to below the first line.

In the vehicle and the control method therefor, the avoidance control may be control for prohibiting execution of the rectangular-wave control over the motor.

In the vehicle and the control method therefor, the avoidance control may be control for correcting the detected rotation angle of the rotor, which is used to calculate the estimated torque, such that the estimated torque is increased.

In the vehicle and the control method therefor, an estimated torque of the motor may be calculated using the detected rotation angle of the rotor and then feedback control may be executed over the motor on the basis of a deviation between the estimated torque and a command torque of the motor when the rectangular-wave control is executed. The avoidance control may be control for correcting the estimated torque to increase the estimated torque, the estimated torque being calculated using the detected rotation angle of the rotor.

In the vehicle and the control method therefor, the avoidance control may be control for indirectly correcting the estimated torque to increase the estimated torque by correcting the detected rotation angle or the avoidance control may be control for directly correcting the estimated torque to increase the estimated torque by increasing the estimated torque by a predetermined value.

In the vehicle and the control method therefor, an estimated torque of the motor may be calculated using the detected rotation angle of the rotor and then feedback control may be executed over the motor on the basis of a deviation between the estimated torque and a command torque of the motor when the rectangular-wave control is executed. The avoidance control may be control for limiting a rate of change in the command torque to below a predetermined value.

With the vehicle and the control method therefor according to the invention, in the vehicle that executes rectangular-wave control over the motor using an output of the resolver, it is possible to avoid a rapid variation in output torque of the motor even during not-yet zero learning.

## BRIEF DESCRIPTION OF THE DRAWINGS

Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be

described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a schematic configuration view of a vehicle according to an embodiment;

FIG. 2 is a view for illustrating control modes of a motor mounted on the vehicle;

FIG. 3 is a graph that shows the correlation between a PWM control region and a rectangular-wave voltage control region for the control modes of the motor;

FIG. 4 is a control block diagram of the PWM control;

FIG. 5 is a control block diagram of the rectangular-wave voltage control;

FIG. 6 is a graph for illustrating a technique for zero learning that is executed by a zero learning unit in the rectangular-wave voltage control shown in FIG. 5;

FIG. 7 is a view for illustrating rapid torque variation avoidance control that is executed by a phase limiter in the rectangular-wave voltage control shown in FIG. 5;

FIG. 8 is a graph for illustrating a first alternative embodiment of the rapid torque variation avoidance control;

FIG. 9 is a graph for illustrating a second alternative embodiment of the rapid torque variation avoidance control;

FIG. 10 is a control block diagram of rectangular-wave voltage control according to a second embodiment of the invention;

FIG. 11 is a graph that shows the correlation between an actual torque and estimated torque  $Trq$  of a motor according to the second embodiment of the invention;

FIG. 12 is a graph that shows the correlation between a command torque  $Trq_{com}$  and an actual torque according to the second embodiment of the invention;

FIG. 13 is a control block diagram of rectangular-wave voltage control according to a first alternative embodiment to the second embodiment of the invention;

FIG. 14 is a graph for illustrating a technique for correcting a d-axis current  $I_d$  and a q-axis current  $I_q$  according to the first alternative embodiment to the second embodiment of the invention;

FIG. 15 is a control block diagram of rectangular-wave voltage control according to a second alternative embodiment to the second embodiment of the invention; and

FIG. 16 is a control block diagram of rectangular-wave voltage control according to a third alternative embodiment to the second embodiment of the invention.

#### DETAILED DESCRIPTION OF EMBODIMENTS

Hereinafter, embodiments of the invention will be described in detail with reference to the accompanying drawings. Like reference numerals denote the same or corresponding portions in the drawings, and the description thereof will not be repeated basically.

FIG. 1 is a schematic configuration view of a vehicle 100 according to a first embodiment of the invention. The vehicle 100 includes a direct-current voltage generating unit 10#, a smoothing capacitor C0, an inverter 14, a control device (ECU) 30 and a motor M1.

The motor M1 is an alternating-current synchronous motor including a rotor, and is, for example, a permanent magnet-type synchronous motor that uses a permanent magnet for the rotor. The motor M1 has a salient inductance (characteristic that a d-axis inductance and a q-axis inductance differ from each other).

In the present embodiment, the motor M1 is a drive motor that generates torque for driving drive wheels of an electromotive vehicle, such as a hybrid vehicle and an electric

vehicle. The electromotive vehicle includes overall vehicles on which a motor for generating vehicle driving force is mounted, and includes an electric vehicle on which no engine is mounted. The motor M1 is generally configured to also function as a generator.

The direct-current voltage generating unit 10# includes a direct-current power supply B, system relays SR1, SR2, a smoothing capacitor C1 and a converter 12.

The direct-current power supply B is formed of a secondary battery configured to include nickel metal hydrides, lithium ions, or the like, a fuel cell, an electric double layer capacitor or a combination of any two or more of them. The voltage (Vb), current and temperature of the direct-current power supply B are detected by a monitoring unit 10 provided at the direct-current power supply B. Detected values of the monitoring unit 10 are output to the control device 30.

The system relay SR1 is connected between the positive electrode terminal of the direct-current power supply B and a power line 6, and the system relay SR2 is connected between the negative electrode terminal of the direct-current power supply B and a power line 5. The system relays SR1, SR2 are turned on or off by a signal SE from the control device 30. The smoothing capacitor C1 is connected between the power line 6 and the power line 5. A direct-current voltage VL between the power line 6 and the power line 5 is detected by a voltage sensor 11. A detected value of the voltage sensor 11 is transmitted to the control device 30.

The converter 12 includes a reactor L1, power semiconductor switching elements Q1, Q2, and diodes D1, D2 (also referred to as antiparallel diodes).

The power semiconductor switching elements Q1, Q2 are serially connected between the power line 7 and the power line 5. On/off states of the power semiconductor switching elements Q1, Q2 are controlled by switching control signals S1, S2 from the control device 30.

In the embodiment of the invention, each of the power semiconductor switching elements (hereinafter, simply referred to as "switching elements") may be an insulated gate bipolar transistor (IGBT), a power metal oxide semiconductor (MOS) transistor, a power bipolar transistor, or the like. The antiparallel diodes D1, D2 are respectively connected to the switching elements Q1, Q2.

The reactor L1 is connected between a connection node of the switching elements Q1, Q2 and the power line 6. In addition, the smoothing capacitor C0 is connected between the power line 7 and the power line 5.

The inverter 14 is formed of a U-phase arm 15, a V-phase arm 16 and a W-phase arm 17 that are provided in parallel between the power line 7 and the power line 5. The arm of each phase is formed of switching elements serially connected between the power line 7 and the power line 5. For example, the U-phase arm 15 includes switching elements Q3, Q4. The V-phase arm 16 includes switching elements Q5, Q6. The W-phase arm 17 includes switching elements Q7, Q8. Antiparallel diodes D3 to D8 are respectively connected to the switching elements Q3 to Q8. On/off states of the switching elements Q3 to Q8 are controlled by switching control signals S3 to S8 from the control device 30.

A midpoint of the arm of each phase is connected to the end of a corresponding one of the three-phase coils of the motor M1. One ends of the three U, V, W-phase coils are commonly connected to a neutral point 26.

The converter 12 carries out switching operations in response to the switching control signals S1, S2 from the control device 30. At the time of step-up operation, the converter 12 steps up the direct-current voltage VL, which is supplied from the direct-current power supply B, to a direct-

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current voltage  $V_H$  (which corresponds to an input voltage to the inverter **14**, and, hereinafter, this direct-current voltage is also termed "system voltage"). At the time of step-down operation, the converter **12** steps down the direct-current voltage  $V_H$  to the direct-current voltage  $V_L$ . A voltage conversion ratio (the ratio of  $V_H$  and  $V_L$ ) in the step-up operation or the step-down operation is controllable by adjusting control duty ratios of the switching elements **Q1**, **Q2**. When the converter **12** is stopped,  $V_H = V_L$  (voltage conversion ratio=1.0) is obtained.

The smoothing capacitor **C0** smoothes the direct-current voltage applied to the power line **7**. The voltage sensor **13** detects the voltage between both ends of the smoothing capacitor **C0**, that is, the system voltage  $V_H$ , and outputs the detected value to the control device **30**.

The inverter **14** carries out switching operations in response to the switching control signals **S3** to **S8** from the control device **30**. When a torque command value of the motor **M1** is positive ( $Trqcom > 0$ ), the inverter **14** converts the direct-current voltage applied to the power line **7** to alternating-current voltages, and drives the motor **M1** such that the motor **M1** outputs a positive torque. When the torque command value of the motor **M1** is zero ( $Trqcom = 0$ ), the inverter **14** converts the direct-current voltage to alternating-current voltages, and drives the motor **M1** such that the torque becomes zero. Thus, the motor **M1** is driven so as to generate zero or positive torque specified by the command torque  $Trqcom$ .

At the time of regenerative braking of the vehicle **100**, the command torque  $Trqcom$  of the motor **M1** is set to a negative value ( $Trqcom < 0$ ). In this case, the inverter **14** converts alternating-current voltages generated by the motor **M1** to direct-current voltage, and supplies the converted direct-current voltage (system voltage) to the converter **12** via the smoothing capacitor **C0**.

A current sensor **24** detects currents (phase currents) flowing through the motor **M1**, and outputs the detected values to the control device **30**. The sum of instantaneous values of three-phase currents  $i_u$ ,  $i_v$ ,  $i_w$  is zero, so the current sensor **24** may be configured to detect two-phase motor currents (for example, the V-phase current  $i_v$  and the W-phase current  $i_w$ ) as shown in FIG. 1.

A resolver **25** detects a rotor rotation angle (magnetic pole positions of the rotor) of the motor **M1**, and transmits the detected rotor rotation angle to the control device **30**. In the following description, the rotor rotation angle detected by the resolver **25** is referred to as "detected rotor angle  $\theta_c$ ". As will be described later, the control device **30** controls the output of the motor **M1** using the detected rotor angle  $\theta_c$ .

The control device **30** is formed of an electronic control unit (ECU), and controls devices of the vehicle **100** through software processing in which a prestored program is executed in a central processing unit (CPU) (not shown) and/or hardware processing of an exclusive electronic circuit.

For example, the control device **30** generates the switching control signals **S1**, **S2** for bringing the system voltage  $V_H$  into coincidence with a voltage command value, and outputs the switching control signals **S1**, **S2** to the converter **12**. In addition, the control device **30** generates the switching control signals **S3** to **S8** such that the motor **M1** outputs a torque according to the command torque  $Trqcom$  through a control mode (described later), and outputs the switching control signals **S3** to **S8** to the inverter **14**.

FIG. 2 is a view for illustrating control modes of the motor **M1**. The control device **30** controls the motor **M1** in a pulse width modulation (PWM) control mode or a rectangular-wave voltage control mode.

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The PWM control mode includes two control modes, that is, a sinusoidal PWM control mode and an overmodulation PWM control mode. Sinusoidal PWM control is used as a general PWM control mode, and on/off states of each pair of switching elements of a corresponding one of the three-phase arms are controlled in accordance with a voltage comparison between a sinusoidal voltage command value and a carrier wave (typically, triangular wave). Overmodulation PWM control is to distort the amplitude of the carrier wave such that the amplitude is reduced and then to execute PWM control similar to the above-described sinusoidal PWM control. In these PWM control modes, it is just possible to increase a modulation factor to the range around 0.78.

On the other hand, rectangular-wave voltage control is to apply one rectangular-wave pulse, of which the ratio of the high-level period and the low-level period is 1 to 1, to the motor **M1**, and corresponds to the case where a PWM duty ratio is kept at the maximum value. Thus, the modulation factor is increased to about 0.78.

The above-described PWM control and rectangular-wave voltage control are known control modes, so the detailed description will not be repeated here.

FIG. 3 is a graph that shows the correlation between a PWM control region and a rectangular-wave voltage control region. A motor operation point that is determined on the basis of the rotation speed and torque of the motor **M1** is controlled in a region lower than an upper limit line shown in FIG. 3. Within the region lower than the upper limit line, a low torque and low rotation speed-side region **A1** with respect to a boundary line shown in FIG. 3 is a PWM control region, and a high torque and high rotation speed-side region **A2** with respect to the boundary line is a rectangular-wave voltage control region. The control device **30** controls the motor **M1** in the PWM control mode when the motor operation point falls within the region **A1**, and controls the motor **M1** in the rectangular-wave voltage control mode when the motor operation point falls within the region **A2**.

In any control mode, a rotating coordinate system having a magnetic flux direction (d axis) of the permanent magnet of the rotor and a direction (q axis) perpendicular to the magnetic flux direction is used in control over the motor **M1**. The rotating coordinate system is recognized on the basis of the detected rotor angle  $\theta_c$ . In the following description, as distinguished from actual d axis, q axis and d-q axes, d axis, q axis and d-q axes recognized on the basis of the detected rotor angle  $\theta_c$  in control are respectively referred to as "dc axis", "qc axis" and "dc-qc axes".

Next, PWM control will be described. FIG. 4 is a control block diagram of PWM control that is executed by the control device **30**. The control device **30** includes a PWM control unit **200** that executes PWM control. The PWM control unit **200** includes a current command generating unit **210**, coordinate conversion units **220**, **250**, a PI operation unit **240**, a PWM signal generating unit **260** and a zero learning unit **270**.

The current command generating unit **210** generates a d-axis current command value  $I_{dcom}$  and a q-axis current command value  $I_{qcom}$  based on the command torque  $Trqcom$  in accordance with a prepared table, or the like.

The zero learning unit **270** recognizes the dc-qc axes (d-q axes in control) on the basis of the detected rotor angle  $\theta_c$ , and calculates a difference between the recognized dc-qc axes and actual d-q axes (hereinafter, referred to as "zero offset error  $\Delta\theta$ ").

The zero offset error  $\Delta\theta$  is an error that arises due to a deviation of a mounting position of the resolver **25** with respect to a coil position of the motor **M1**, and corresponds to a difference between the origin of the detected rotor angle  $\theta_c$



and the origin of the actual rotor rotation angle  $\theta$ . The zero offset error  $\Delta\theta$  is constant irrespective of the detected rotor angle  $\theta_c$ , and is an error different from an error (so-called periodical error) that periodically fluctuates on the basis of the detected rotor angle  $\theta_c$ . Hereinafter, control for calculating the zero offset error  $\Delta\theta$  is also simply referred as “zero learning”. A technique for zero learning will be described in detail later.

When the zero learning unit 270 has completed zero learning, the zero learning unit 270 corrects the detected rotor angle  $\theta_c$  using the zero offset error  $\Delta\theta$  obtained through zero learning, and outputs the corrected detected rotor angle  $\theta_c$  as a “learned rotor angle  $\theta_{c\#}$ ”. When the zero learning unit 270 has not completed zero learning, the zero learning unit 270 directly outputs the detected rotor angle  $\theta_c$  output from the resolver 25.

The coordinate conversion unit 220 calculates a d-axis current  $I_d$  and a q-axis current  $I_q$  on the basis of the V-phase current  $i_v$  and the W-phase current  $i_w$  detected by the current sensor 24 through coordinate conversion (three phases to two phases) using the output (the learned rotor angle  $\theta_{c\#}$  or the detected rotor angle  $\theta_c$ ) of the zero learning unit 270.

A deviation  $\Delta I_d$  of the d-axis current from the command value ( $\Delta I_d = I_{dcom} - I_d$ ) and a deviation  $\Delta I_q$  of the q-axis current from the command value ( $\Delta I_q = I_{qcom} - I_q$ ) are input to the PI operation unit 240. The PI operation unit 240 obtains a control deviation by performing PI operation on the d-axis current deviation  $\Delta I_d$  and the q-axis current deviation  $\Delta I_q$  using a predetermined gain, and generates a d-axis voltage command value  $V_{d\#}$  and a q-axis voltage command value  $V_{q\#}$  based on the control deviation.

The coordinate conversion unit 250 converts the d-axis voltage command value  $V_{d\#}$  and the q-axis voltage command value  $V_{q\#}$  to U-phase, V-phase and W-phase voltage command values  $V_u$ ,  $V_v$ ,  $V_w$  through coordinate conversion (two phases to three phases) using the output (the learned rotor angle  $\theta_{c\#}$  or the detected rotor angle  $\theta_c$ ) of the zero learning unit 270. The system voltage  $V_H$  is also reflected in conversion from the d-axis and q-axis voltage command values  $V_{d\#}$ ,  $V_{q\#}$  to the three-phase voltage command values  $V_u$ ,  $V_v$ ,  $V_w$ .

The PWM signal generating unit 260 generates the switching control signals S3 to S8 shown in FIG. 1 on the basis of a comparison between the three-phase voltage command values  $V_u$ ,  $V_v$ ,  $V_w$  and a predetermined carrier wave (carrier signal). The inverter 14 is subjected to switching control in accordance with the switching control signals S3 to S8. Thus, alternating-current voltages for outputting a torque according to the command torque  $Trq_{com}$  input to the current command generating unit 210 are applied to the motor M1.

In this way, in PWM control, current feedback control is executed such that the motor currents ( $I_d$ ,  $I_q$ ) follow the current command values ( $I_{dcom}$ ,  $I_{qcom}$ ) based on the command torque  $Trq_{com}$ .

Next, rectangular-wave voltage control will be described. FIG. 5 is a control block diagram of rectangular-wave voltage control that is executed by the control device 30. The control device 30 includes a rectangular-wave voltage control unit 400 that executes rectangular-wave voltage control. The rectangular-wave voltage control unit 400 includes the coordinate conversion unit 220, the zero learning unit 270, a torque estimating unit 420, a PI operation unit 430, a phase limiter 432, a rectangular wave generating unit 440 and a signal generating unit 450.

As in the case of the PWM control mode, the zero learning unit 270 outputs the learned rotor angle  $\theta_{c\#}$  when the zero learning unit 270 has completed zero learning, and directly

outputs the detected rotor angle  $\theta_c$  when the zero learning unit 270 has not completed zero learning.

As in the case of the PWM control mode, the coordinate conversion unit 220 converts the three-phase currents, obtained from the V-phase current  $i_v$  and the W-phase current  $i_w$ , to the d-axis current  $I_d$  and the q-axis current  $I_q$  using the output (the learned rotor angle  $\theta_{c\#}$  or the detected rotor angle  $\theta_c$ ) of the zero learning unit 270.

The torque estimating unit 420 estimates the output torque of the motor M1 using the d-axis current  $I_d$  and q-axis current  $I_q$  obtained with the use of the coordinate conversion unit 220. The torque estimating unit 420 is, for example, formed of a torque calculation map that outputs an estimated torque  $Trq$  using the d-axis current  $I_d$  and the q-axis current  $I_q$  as arguments.

A deviation  $\Delta Trq$  of the estimated torque  $Trq$  with respect to the command torque  $Trq_{com}$  ( $\Delta Trq = Trq_{com} - Trq$ ) is input to the PI operation unit 430. The PI operation unit 430 obtains a control deviation by performing PI operation over the torque deviation  $\Delta Trq$  using a predetermined gain, and sets a phase  $\phi$  of rectangular-wave voltage on the basis of the obtained control deviation. The PI operation unit 430 advances the phase  $\phi$  when the deviation  $\Delta Trq$  is positive; otherwise, the PI operation unit 430 retards the phase  $\phi$ . In this way, in rectangular-wave voltage control, the estimated torque  $Trq$  is caused to follow the command torque  $Trq_{com}$  by adjusting the phase  $\phi$  of rectangular-wave voltage.

The phase limiter 432 outputs a voltage phase  $\phi_v$  to the rectangular wave generating unit 440. The voltage phase  $\phi_v$  is obtained by setting a predetermined limit to the phase  $\phi$  that is output from the PI operation unit 430. In the present embodiment, the phase limiter 432 executes control for avoiding a rapid variation in the output of the motor M1 (hereinafter, also referred to as “rapid torque variation avoidance control”) during not-yet zero learning. Specifically, the phase limiter 432 limits the control range of the phase  $\phi$  during not-yet zero learning as compared to the control range of the phase  $\phi$  after zero learning (during normal times). This is the most characterizing point in the present embodiment. Rapid torque variation avoidance control (a technique for limiting the phase  $\phi$ ) that is executed by the phase limiter 432 will be described in detail later.

The rectangular wave generating unit 440 generates the three-phase voltage command values (rectangular-wave pulses)  $V_u$ ,  $V_v$ ,  $V_w$  in accordance with the voltage phase  $\phi_v$  output from the phase limiter 432. The signal generating unit 450 generates the switching control signals S3 to S8 in accordance with the three-phase voltage command values  $V_u$ ,  $V_v$ ,  $V_w$ . The inverter 14 performs switching operations in accordance with the switching control signals S3 to S8. Thus, rectangular-wave pulsed voltages according to the voltage phase  $\phi_v$  are respectively applied to the three phases of the motor M1.

In this way, in rectangular-wave voltage control, torque feedback control is executed such that the estimated torque  $Trq$  of the motor M1 is caused to follow the command torque  $Trq_{com}$ .

Next, zero learning will be described. FIG. 6 is a view for illustrating a technique for zero learning that is executed by the above-described zero learning unit 270. The technique for zero learning is not necessarily limited to a technique described below.

Generally, the voltage equation of the motor is simply expressed by the following mathematical expression (1).

$$V_d = -\omega L I_d, V_q = \omega L I_q + \omega \Phi \quad (1)$$

In the mathematical expression (1), “ $\omega$ ” denotes an electric angular velocity, “ $L_d$ ” denotes a d-axis inductance, “ $L_q$ ” denotes a q-axis inductance, and “ $\Phi$ ” denotes the number of armature flux linkages.

In a state where no current is flowing through the motor M1 ( $I_d=I_q=0$ ) and the motor M1 is rotating ( $\omega$  is not 0),  $V_d=0$  and  $V_q=\omega\Phi$  are obtained from the mathematical expression (1), and a counter electromotive voltage of  $\omega\Phi$  is applied to only the q axis. However, as shown in FIG. 6, if there is a zero offset error  $\Delta\theta$  between the dc-qc axes in control and the actual d-q axes, it is recognized that the counter electromotive voltage  $\omega\Phi$  is applied to not only the qc axis but also the dc axis in control, so it is not recognized that the motor current is 0.

The zero learning unit 270 executes zero learning by utilizing such a phenomenon. Specifically, the zero learning unit 270 determines whether a learning permission condition is satisfied. The learning permission condition is satisfied in a state where no current is flowing through the motor M1 and the motor M1 is rotating. When the learning permission condition is satisfied, the zero learning unit 270 rotates the dc-qc axes in predetermined angles, and determines whether the motor current is recognized as 0. The zero learning unit 270 learns the rotation angle of the dc-qc axes, at which the motor current is recognized as 0, as the zero offset error  $\Delta\theta$ .

Next, rapid torque variation avoidance control will be described. As described above, the zero learning unit 270 executes zero learning when the learning permission condition is satisfied. After completion of zero learning, the zero learning unit 270 outputs the “learned rotor angle  $\theta_c$ ” obtained by correcting the detected rotor angle  $\theta_c$  using the zero offset error  $\Delta\theta$ .

However, during not-yet zero learning, the zero learning unit 270 directly outputs the detected rotor angle  $\theta_c$ , detected by the resolver 25, to the coordinate conversion unit 220. Therefore, during not-yet zero learning, there arises an error based on the zero offset error  $\Delta\theta$  in the d-axis current  $I_d$  and the q-axis current  $I_q$  that are calculated by the coordinate conversion unit 220. As a result, particularly, in torque feedback control within rectangular-wave voltage control, there arises an error in the estimated torque  $T_r$  estimated by the torque estimating unit 420, and there is a concern that the output torque of the motor M1 rapidly varies.

As control for avoiding such a rapid torque variation (rapid torque variation avoidance control), the phase limiter 432 according to the present embodiment limits the control range of the rectangular-wave voltage phase  $\phi$  during not-yet zero learning as compared to the control range of the rectangular-wave voltage phase  $\phi$  after completion of zero learning (during normal times) as described above.

FIG. 7 is a graph for illustrating rapid torque variation avoidance control (technique for limiting the phase  $\phi$ ) that is executed by the phase limiter 432. As shown in FIG. 7, the output torque of the motor M1 varies on the basis of the phase  $\phi$  of rectangular-wave voltage. Specifically, when the phase  $\phi$  is 0, the output torque is 0. In the region in which the voltage phase  $\phi$  is larger than 0 (advanced region), the output torque is a positive value, and the output torque is maximum at  $\phi=\phi_2$ . In the region in which the voltage phase  $\phi$  is smaller than 0 (retarded region), the output torque is a negative value, and the output torque is minimum at  $\phi=-\phi_2$ .

The phase limiter 432 determines whether zero learning has been completed. When zero learning has been completed (during normal times), the phase limiter 432 limits the phase  $\phi$  to the range of  $-\phi_2$  to  $\phi_2$ . On the other hand, when zero learning has not been completed yet, the phase limiter 432 limits the phase  $\phi$  to the range of  $-\phi_1$  ( $>-\phi_2$ ) to  $\phi_1$  ( $<\phi_2$ ). In this way, the phase limiter 432 limits the control range ( $-\phi_1$  to

$\phi_1$ ) of the phase  $\phi$  during not-yet zero learning as compared to the control range ( $-\phi_2$  to  $\phi_2$ ) of the phase  $\phi$  during normal times. Thus, during not-yet zero learning, in rectangular-wave voltage control, control is avoided in a high torque region (which means a region in which the absolute value of torque is large, and regions  $\alpha$ ,  $\beta$  in the example of FIG. 7) in which the influence of the zero offset error  $\Delta\theta$  is particularly large. Therefore, even during not-yet zero learning, it is possible to avoid a rapid variation in output torque.

As described above, in the present embodiment, the control range of the phase  $\phi$  of rectangular-wave voltage during not-yet zero learning is limited as compared to that during normal times (after completion of zero learning). Thus, control is avoided in a high torque region in which the influence of the zero offset error  $\Delta\theta$  is particularly large. Therefore, it is possible to avoid a rapid variation in output torque even during not-yet zero learning.

Next, a first alternative embodiment to the first embodiment will be described. In rapid torque variation avoidance control according to the above-described first embodiment, the control range of the phase  $\phi$  of rectangular-wave voltage during not-yet zero learning is limited as compared to that during normal times in order to avoid control in a high torque region in which the influence of the zero offset error  $\Delta\theta$  is particularly large.

In contrast to this, in rapid torque variation avoidance control according to the first alternative embodiment, torque during not-yet zero learning is limited as compared to that during normal times in rectangular-wave voltage control in order to further directly avoid control in a high torque region.

FIG. 8 is a graph for illustrating an example of rapid torque variation avoidance control (torque limiting) according to the first alternative embodiment. In the first alternative embodiment, a split line (see the alternate long and short dashes line) that splits the rectangular-wave voltage control region A2 into a high torque and high rotation speed-side region and a low torque and low rotation speed-side region is provided. During rectangular-wave voltage control, the control device 30 sets the setting range of the command torque  $T_{rqcom}$  to all the rectangular-wave voltage control region A2 during normal times (after completion of zero learning), and limits the setting range of the command torque  $T_{rqcom}$  to the low torque and low rotation speed-side region with respect to the split line during not-yet zero learning. That is, during rectangular-wave voltage control, the upper limit of the command torque  $T_{rqcom}$  is set to the upper limit line during normal times (after completion of zero learning), and the upper limit of the command torque  $T_{rqcom}$  is set to the split line on a lower torque side than the upper limit line during not-yet zero learning.

Thus, setting of the command torque  $T_{rqcom}$  to a high torque region that exceeds the split line is avoided during not-yet zero learning. Therefore, as in the case of the first embodiment, it is possible to avoid a rapid variation in output torque even during not-yet zero learning.

Next, a second alternative embodiment to the first embodiment will be described. As another technique for directly avoiding control in a high torque region, execution of rectangular-wave voltage control may be prohibited and the control mode of the motor M1 may be fixed to the PWM control mode during not-yet zero learning.

FIG. 9 is a graph for illustrating rapid torque variation avoidance control (prohibition of rectangular-wave voltage control) according to the second alternative embodiment. In the second alternative embodiment, the control device 30 allows setting of the command torque  $T_{rqcom}$  in the rectangular-wave voltage control region A2 during normal times (after completion of zero learning), and prohibits setting of

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the command torque  $Trq_{com}$  in the rectangular-wave voltage control region A2 during not-yet zero learning. In other words, the upper limit of the command torque  $Trq_{com}$  is set to the upper limit line during normal times (after completion of zero learning), and the upper limit of the command torque  $Trq_{com}$  is set to the boundary line on a lower torque side than the upper limit line during not-yet zero learning.

Thus, during not-yet zero learning, rectangular-wave voltage control is prohibited, and the control mode of the motor M1 is fixed to the PWM control mode. Therefore, during not-yet zero learning, setting of the command torque  $Trq_{com}$  to the region A2 that is a relatively high torque region is avoided. Therefore, as in the case of the first embodiment, it is possible to avoid a rapid variation in output torque even during not-yet zero learning.

Next, a second embodiment will be described. In rapid torque variation avoidance control according to the above-described first embodiment, control is avoided in a high torque region (regions  $\alpha$ ,  $\beta$  in FIG. 7) in which the influence of the zero offset error  $\Delta\theta$  is large during not-yet zero learning. Therefore, during not-yet zero learning, it is possible to avoid a rapid variation in output torque, while, on the other hand, it is not possible to output high torque.

In rapid torque variation avoidance control according to the second embodiment, when rectangular-wave voltage control is executed, the detected rotor position  $\theta_c$  that is used to calculate the estimated torque  $Trq$  is corrected by a predetermined technique such that a rapid variation in output torque is avoided while control is allowed in a high torque region during not-yet zero learning. The other structures, functions and processes are the same as those of the above-described first embodiment, so the detailed description will not be repeated.

Hereinafter, rapid torque variation avoidance control (correcting the detected rotor position  $\theta_c$ ) according to the second embodiment will be described. FIG. 10 is a control block diagram of rectangular-wave voltage control that is executed by a rectangular-wave voltage control unit 400A according to the second embodiment. The rectangular-wave voltage control unit 400A differs from the above-described rectangular-wave voltage control unit 400 shown in FIG. 5 in that the phase limiter 432 is changed to a phase limiter 432A and a correction unit 271 is further added. The other functional blocks have been already described, so the detailed description will not be repeated.

The phase limiter 432A outputs a voltage phase  $\phi_v$  to the rectangular wave generating unit 440. The voltage phase  $\phi_v$  is obtained by setting a predetermined limit to the phase  $\phi$  that is output from the PI operation unit 430. At this time, even during not-yet zero learning, the phase limiter 432A sets the control range of the phase  $\phi$  to the above-described range of  $-\phi_2$  to  $\phi_2$  shown in FIG. 7 as well as during normal times (after zero learning). Thus, even during not-yet zero learning, control is allowed in a high torque region (regions  $\alpha$ ,  $\beta$  in FIG. 7).

During not-yet zero learning, the correction unit 271 corrects the detected rotor angle  $\theta_c$  output from the zero learning unit 270 with the use of a predetermined technique, and outputs the corrected detected rotor angle  $\theta_c$  to the coordinate conversion unit 220 as "corrected rotor angle  $\theta_c$ ". After zero learning, the correction unit 271 directly outputs the learned rotor angle  $\theta_c$  output from the zero learning unit 270 to the coordinate conversion unit 220. Thus, in the coordinate conversion unit 220, coordinate conversion is carried out using the corrected rotor angle  $\theta_c$  during not-yet zero learning, and coordinate conversion is carried out using the learned rotor angle  $\theta_c$  after zero learning.

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FIG. 11 is a graph that shows an example of the correlation between an actual torque of the motor M1 and an estimated torque  $Trq$  that is estimated by the torque estimating unit 420 during not-yet zero learning. FIG. 12 is a graph that shows the correlation between a command torque  $Trq_{com}$  and an actual torque in the case where there is a correlation between an actual torque and an estimated torque  $Trq$  as shown in FIG. 11.

As described above, in rectangular-wave voltage control, torque feedback control is executed such that the estimated torque  $Trq$  is caused to follow the command torque  $Trq_{com}$ . Therefore, when the estimated torque  $Trq$  is calculated so as to be smaller than the actual torque due to the influence of zero error as shown in FIG. 11, the rectangular-wave voltage phase  $\phi$  is advanced with respect to a proper value through the action of torque feedback control, so the actual torque is excessively larger than the command torque  $Trq_{com}$  as shown in FIG. 12. Such a phenomenon becomes a factor of a rapid torque variation.

On the contrary to the example shown in FIG. 11, when the estimated torque  $Trq$  is calculated so as to be larger than the actual torque due to the influence of zero error, the rectangular-wave voltage phase  $\phi$  is retarded with respect to a proper value through the action of torque feedback control, so the actual torque is smaller than the command torque  $Trq_{com}$ . However, in this case, the actual torque is smaller than the torque required by a user (command torque  $Trq_{com}$ ), so a rapid torque variation does not become a significant issue.

During not-yet zero learning, the correction unit 271 corrects the detected rotor position  $\theta_c$  by a predetermined angular correction amount  $\theta_h$  such that the estimated torque  $Trq$  that is estimated by the torque estimating unit 420 is increased.

Specifically, the correction unit 271 determines whether the sign of the command torque  $Trq_{com}$  (which may be the last value of the q-axis current  $I_q$ ) is positive or negative. When  $Trq_{com} \geq 0$ , the direction in which the estimated torque  $Trq$  increases is a positive direction, so the correction unit 271 calculates the corrected rotor angle  $\theta_c'$  by  $\theta_c' = \theta_c + \theta_h$ . On the other hand, when  $Trq_{com} < 0$ , the direction in which the estimated torque  $Trq$  increases is a negative direction, so the correction unit 271 calculates the corrected rotor angle  $\theta_c'$  by  $\theta_c' = \theta_c - \theta_h$ .

Where the number of pole pairs of the motor M1 is "p" and the number of poles of the resolver 25 is "R", an electric angle  $\theta_e$  may be expressed by  $\theta_e = \theta_c \times p/R$ . Therefore, the d-axis current  $I_d$  and the q-axis current  $I_q$  that are calculated by the coordinate conversion unit 220 are respectively the following mathematical expressions (1), (2).

$$I_d = \sqrt{2} \times \left\{ i_u \times \sin\left(\theta_e + \frac{2}{3}\pi\right) - i_w \times \sin(\theta_e) \right\} \quad (1)$$

$$I_q = \sqrt{2} \times \left\{ i_u \times \cos\left(\theta_e + \frac{2}{3}\pi\right) - i_w \times \cos(\theta_e) \right\} \quad (2)$$

As described above, in the second embodiment, when rectangular-wave voltage control is executed, the detected rotor position  $\theta_c$  is corrected in advance such that the estimated torque  $Trq$  is increased while control is allowed in a high torque region during not-yet zero learning. Therefore, an excessive increase in actual torque with respect to the command torque  $Trq_{com}$  is suppressed through the action of torque feedback control in rectangular-wave voltage control.

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Therefore, even during not-yet zero learning, it is possible to avoid a rapid variation in output torque while allowing control in a high torque region.

Next, a first alternative embodiment to the second embodiment will be described. In rapid torque variation avoidance control according to the above-described second embodiment, when rectangular-wave voltage control is executed, the detected rotor position  $\theta_c$  that is used in coordinate conversion by the coordinate conversion unit 220 is corrected such that the estimated torque  $Trq$  is increased during not-yet zero learning.

In contrast to this, in rapid torque variation avoidance control according to the first alternative embodiment, the result of coordinate conversion (the d-axis current  $I_d$  and the q-axis current  $I_q$ ) carried out by the coordinate conversion unit 220 is corrected such that the estimated torque  $Trq$  is increased.

Hereinafter, rapid torque variation avoidance control (correcting the d-axis current  $I_d$  and the q-axis current  $I_q$ ) according to the first alternative embodiment will be described. FIG. 13 is a control block diagram of rectangular-wave voltage control that is executed by a rectangular-wave voltage control unit 400B according to the first alternative embodiment. The rectangular-wave voltage control unit 400B differs from the rectangular-wave voltage control unit 400A shown in FIG. 10 in that the correction unit 271 is deleted and a correction unit 221 is added. The other functional blocks have been already described, so the detailed description will not be repeated.

During not-yet zero learning, the correction unit 221 corrects the d-axis current  $I_d$  and the q-axis current  $I_q$ , calculated by the coordinate conversion unit 220, using the detected rotor angle  $\theta_c$ , and outputs the corrected d-axis current  $I_d$  and the corrected q-axis current  $I_q$  to the torque estimating unit 420 as "corrected d-axis current  $I_d$ " and "corrected q-axis current  $I_q$ ", respectively.

After zero learning, the correction unit 221 directly outputs the d-axis current  $I_d$  and the q-axis current  $I_q$ , calculated by the coordinate conversion unit 220 using the learned rotor angle  $\theta_{c\#}$ , to the torque estimating unit 420.

FIG. 14 is a view for illustrating a technique for correcting the d-axis current  $I_d$  and the q-axis current  $I_q$  with the use of the correction unit 221. As shown in FIG. 14, where a pre-corrected current phase with reference to the d axis is denoted by " $\phi_i$ ", a correction amount of the current phase  $\phi_i$  is denoted by " $\phi_{ih}$ " and the square root of  $(I_q^2 + I_d^2)$  is denoted by " $I_r$ ", the correction unit 221 calculates the corrected d-axis current  $I_d'$  and the corrected q-axis current  $I_q'$  as follows.

The correction unit 221 determines whether the sign of the command torque  $Trq_{com}$  (which may be the last value of the q-axis current  $I_q$ ) is positive or negative. When  $Trq_{com} \geq 0$ , the correction unit 221 calculates the corrected d-axis current  $I_d'$  and the corrected q-axis current  $I_q'$  by  $I_d' = I_r \cos(\phi_i - \phi_{ih})$  and  $I_q' = I_r \sin(\phi_i - \phi_{ih})$ . On the other hand, when the command torque  $Trq_{com} < 0$ , the correction unit 221 calculates the corrected d-axis current  $I_d'$  and the corrected q-axis current  $I_q'$  by  $I_d' = I_r \cos(\phi_i + \phi_{ih})$  and  $I_q' = I_r \sin(\phi_i + \phi_{ih})$ .  $\phi_i$  may be expressed by a  $\tan(I_q/I_d)$ .

As described above, by correcting the d-axis current  $I_d$  and the q-axis current  $I_q$  such that the estimated torque  $Trq$  is increased during not-yet zero learning as well, it is possible to avoid a rapid variation in output torque while control is allowed in a high torque region as in the case of the above-described second embodiment.

Next, a second alternative embodiment to the second embodiment will be described. In rapid torque variation avoidance control according to the above-described second embodiment, when rectangular-wave voltage control is executed, the estimated torque  $Trq$  is indirectly increased by

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correcting the detected rotor position  $\theta_c$  during not-yet zero learning. In contrast to this, in rapid torque variation avoidance control according to the second alternative embodiment, the estimated torque  $Trq$  is directly increased during not-yet zero learning.

Hereinafter, rapid torque variation avoidance control (correcting the estimated torque  $Trq$  such that the estimated torque  $Trq$  increases) will be described. FIG. 15 is a control block diagram of rectangular-wave voltage control that is executed by a rectangular-wave voltage control unit 400C according to the second alternative embodiment. The rectangular-wave voltage control unit 400C differs from the rectangular-wave voltage control unit 400B shown in FIG. 13 in that the correction unit 221 is deleted and a correction unit 421 is added. The other functional blocks have been already described, so the detailed description will not be repeated.

During not-yet zero learning, the correction unit 421 outputs an estimated torque  $Trq'$  obtained as follows. The estimated torque  $Trq$ , calculated by the torque estimating unit 420, is corrected by a predetermined value such that the estimated torque  $Trq$  increases. During normal times (after zero learning), the correction unit 421 directly outputs the estimated torque  $Trq$  calculated by the torque estimating unit 420.

In this way, by directly correcting the estimated torque  $Trq$  such that the estimated torque  $Trq$  increases during not-yet zero learning as well, it is possible to avoid a rapid variation in output torque while control is allowed in a high torque region as in the case of the above-described second embodiment.

Next, a third alternative embodiment to the second embodiment will be described. In rapid torque variation avoidance control according to the above-described second embodiment, when rectangular-wave voltage control is executed, a rapid torque variation is avoided by correcting the detected rotor position  $\theta_c$  in advance such that the estimated torque  $Trq$  is increased during not-yet zero learning. In contrast to this, in rapid torque variation avoidance control according to the third alternative embodiment, a rapid torque variation is avoided by directly limiting the rate of change in the command torque  $Trq_{com}$  during not-yet zero learning.

Hereinafter, rapid torque variation avoidance control (limiting the rate of change in the command torque  $Trq_{com}$ ) according to the third alternative embodiment will be described. FIG. 16 is a control block diagram of rectangular-wave voltage control that is executed by a rectangular-wave voltage control unit 400D according to the third alternative embodiment. The rectangular-wave voltage control unit 400D differs from the rectangular-wave voltage control unit 400A shown in FIG. 10 in that the correction unit 271 is deleted and a limiting unit 422 is added. The other functional blocks have been already described, so the detailed description will not be repeated.

During not-yet zero learning, the rate-of-change limiting unit 422 limits the rate of change in the command torque  $Trq_{com}$  that is used in rectangular-wave voltage control to below a predetermined value. During normal times (after zero learning), the rate-of-change limiting unit 422 does not limit the rate of change in the command torque  $Trq_{com}$  that is used in rectangular-wave voltage control to below the predetermined value. Thus, it is possible to directly suppress a rapid torque variation during not-yet zero learning.

While the invention has been described with reference to example embodiments thereof, it is to be understood that the invention is not limited to the described example embodiments or constructions. To the contrary, the invention is intended to cover various modifications and equivalent

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arrangements. In addition, while the various elements of the example embodiments are shown in various combinations and configurations, other combinations and configurations, including more, less or only a single element, are also within the scope of the invention.

What is claimed is:

1. A vehicle comprising:

a motor having a rotor;

a resolver configured to detect a rotation angle of the rotor; and

a control device configured to execute rectangular-wave control over the motor using the rotation angle of the rotor, the rotation angle being detected by the resolver, the control device being configured to execute zero learning for learning a deviation between an origin of an actual rotation angle of the rotor and an origin of the detected rotation angle of the rotor and then correct the detected rotation angle of the rotor on the basis of a result of the zero learning, and the control device being configured to execute avoidance control for avoiding a rapid variation in output of the motor when the zero learning has not been completed yet,

wherein the control device is configured to calculate an estimated torque of the motor using the detected rotation angle of the rotor and then execute feedback control over the motor on the basis of a deviation between the estimated torque and a command torque of the motor when the rectangular-wave control is executed, the control device is configured to set an upper limit of the command torque during the rectangular-wave control to a first line after the zero learning has been completed, and the avoidance control is control for decreasing the upper limit of the command torque during the rectangular-wave control to below the first line.

2. The vehicle according to claim 1, wherein

the control device is configured to set a control range of a rectangular-wave voltage phase that is used in the rectangular-wave control to a first range after the zero learning has been completed, and the avoidance control is control for limiting the control range of the rectangular-wave voltage phase as compared to the first range.

3. A vehicle comprising:

a motor having a rotor;

a resolver configured to detect a rotation angle of the rotor; and

a control device configured to execute rectangular-wave control over the motor using the rotation angle of the rotor, the rotation angle being detected by the resolver, the control device being configured to execute zero learning for learning a deviation between an origin of an actual rotation angle of the rotor and an origin of the detected rotation angle of the rotor and then correct the detected rotation angle of the rotor on the basis of a result of the zero learning, and the control device being configured to execute avoidance control for avoiding a rapid variation in output of the motor when the zero learning has not been completed yet, wherein

the avoidance control is control for prohibiting execution of the rectangular-wave control over the motor.

4. A vehicle comprising:

a motor having a rotor;

a resolver configured to detect a rotation angle of the rotor; and

a control device configured to execute rectangular-wave control over the motor using the rotation angle of the rotor, the rotation angle being detected by the resolver, the control device being configured to execute zero

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learning for learning a deviation between an origin of an actual rotation angle of the rotor and an origin of the detected rotation angle of the rotor and then correct the detected rotation angle of the rotor on the basis of a result of the zero learning, and the control device being configured to execute avoidance control for avoiding a rapid variation in output of the motor when the zero learning has not been completed yet, wherein

the control device is configured to calculate an estimated torque of the motor using the detected rotation angle of the rotor and then execute feedback control over the motor on the basis of a deviation between the estimated torque and a command torque of the motor when the rectangular-wave control is executed, and the avoidance control is control for correcting the detected rotation angle of the rotor such that the estimated torque is increased, the detected rotation angle being used to calculate the estimated torque.

5. A vehicle comprising:

a motor having a rotor;

a resolver configured to detect a rotation angle of the rotor; and

a control device configured to execute rectangular-wave control over the motor using the rotation angle of the rotor, the rotation angle being detected by the resolver, the control device being configured to execute zero learning for learning a deviation between an origin of an actual rotation angle of the rotor and an origin of the detected rotation angle of the rotor and then correct the detected rotation angle of the rotor on the basis of a result of the zero learning, and the control device being configured to execute avoidance control for avoiding a rapid variation in output of the motor when the zero learning has not been completed yet, wherein

the control device is configured to calculate an estimated torque of the motor using the detected rotation angle of the rotor and then execute feedback control over the motor on the basis of a deviation between the estimated torque and a command torque of the motor when the rectangular-wave control is executed, and the avoidance control is control for correcting the estimated torque to increase the estimated torque, the estimated torque being calculated using the detected rotation angle of the rotor.

6. The vehicle according to claim 5, wherein

the avoidance control is control for indirectly correcting the estimated torque to increase the estimated torque by correcting the detected rotation angle.

7. The vehicle according to claim 5, wherein

the avoidance control is control for directly correcting the estimated torque to increase the estimated torque by increasing the estimated torque by a predetermined value.

8. A vehicle comprising:

a motor having a rotor;

a resolver configured to detect a rotation angle of the rotor; and

a control device configured to execute rectangular-wave control over the motor using the rotation angle of the rotor, the rotation angle being detected by the resolver, the control device being configured to execute zero learning for learning a deviation between an origin of an actual rotation angle of the rotor and an origin of the detected rotation angle of the rotor and then correct the detected rotation angle of the rotor on the basis of a result of the zero learning, and the control device being configured to execute avoidance control for avoiding a rapid

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variation in output of the motor when the zero learning has not been completed yet, wherein the control device is configured to calculate an estimated torque of the motor using the detected rotation angle of the rotor and then execute feedback control over the motor on the basis of a deviation between the estimated torque and a command torque of the motor when the rectangular-wave control is executed, and the avoidance control is control for limiting a rate of change in the command torque to below a predetermined value.

9. A control method for a vehicle including:  
 a motor having a rotor; and  
 a resolver configured to detect a rotation angle of the rotor, the control method comprising:  
 detecting the rotation angle of the rotor with the use of the resolver;  
 executing rectangular-wave control over the motor using the detected rotation angle;  
 executing zero learning for learning a deviation between an origin of an actual rotation angle of the rotor and an origin of the detected rotation angle of the rotor;  
 correcting the detected rotation angle of the rotor on the basis of a result of the zero learning; and  
 executing avoidance control for avoiding a rapid variation in output of the motor when the zero learning has not been completed yet, wherein:  
 an estimated torque of the motor is calculated using the detected rotation angle of the rotor and then feedback control is executed over the motor on the basis of a deviation between the estimated torque and a command torque of the motor when the rectangular-wave control is executed;  
 an upper limit of the command torque during the rectangular-wave control is set to a first line after the zero learning has been completed; and  
 in the avoidance control, the upper limit of the command torque during the rectangular-wave control is decreased to below the first line.

10. The control method according to claim 9, wherein:  
 a control range of a rectangular-wave voltage phase that is used in the rectangular-wave control is set to a first range after the zero learning has been completed; and  
 in the avoidance control, the control range of the rectangular-wave voltage phase is limited as compared to the first range.

11. A control method for a vehicle including:  
 a motor having a rotor; and  
 a resolver configured to detect a rotation angle of the rotor, the control method comprising:  
 detecting the rotation angle of the rotor with the use of the resolver;  
 executing rectangular-wave control over the motor using the detected rotation angle;  
 executing zero learning for learning a deviation between an origin of an actual rotation angle of the rotor and an origin of the detected rotation angle of the rotor;  
 correcting the detected rotation angle of the rotor on the basis of a result of the zero learning; and  
 executing avoidance control for avoiding a rapid variation in output of the motor when the zero learning has not been completed yet, wherein:  
 any one of the rectangular-wave control and a pulse width modulation control is executed over the motor; and  
 in the avoidance control, execution of the rectangular-wave control over the motor is prohibited.

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12. A control method for a vehicle including:  
 a motor having a rotor; and  
 a resolver configured to detect a rotation angle of the rotor, the control method comprising:  
 detecting the rotation angle of the rotor with the use of the resolver;  
 executing rectangular-wave control over the motor using the detected rotation angle;  
 executing zero learning for learning a deviation between an origin of an actual rotation angle of the rotor and an origin of the detected rotation angle of the rotor;  
 correcting the detected rotation angle of the rotor on the basis of a result of the zero learning; and  
 executing avoidance control for avoiding a rapid variation in output of the motor when the zero learning has not been completed yet, wherein:  
 an estimated torque of the motor is calculated using the detected rotation angle of the rotor and then feedback control is executed over the motor on the basis of a deviation between the estimated torque and a command torque of the motor when the rectangular-wave control is executed; and  
 in the avoidance control, the detected rotation angle of the rotor is corrected such that the estimated torque is increased, the detected rotation angle being used to calculate the estimated torque.

13. A control method for a vehicle including:  
 a motor having a rotor; and  
 a resolver configured to detect a rotation angle of the rotor, the control method comprising:  
 detecting the rotation angle of the rotor with the use of the resolver;  
 executing rectangular-wave control over the motor using the detected rotation angle;  
 executing zero learning for learning a deviation between an origin of an actual rotation angle of the rotor and an origin of the detected rotation angle of the rotor;  
 correcting the detected rotation angle of the rotor on the basis of a result of the zero learning; and  
 executing avoidance control for avoiding a rapid variation in output of the motor when the zero learning has not been completed yet, wherein:  
 an estimated torque of the motor is calculated using the detected rotation angle of the rotor and then feedback control is executed over the motor on the basis of a deviation between the estimated torque and a command torque of the motor when the rectangular-wave control is executed; and  
 in the avoidance control, the estimated torque is corrected to increase the estimated torque, the estimated torque being calculated using the detected rotation angle of the rotor.

14. The control method according to claim 13, wherein  
 in the avoidance control, the estimated torque is indirectly corrected to increase the estimated torque by correcting the detected rotation angle.

15. The control method according to claim 13, wherein  
 in the avoidance control, the estimated torque is directly corrected to increase the estimated torque by increasing the estimated torque by a predetermined value.

16. A control method for a vehicle including:  
 a motor having a rotor; and  
 a resolver configured to detect a rotation angle of the rotor, the control method comprising:  
 detecting the rotation angle of the rotor with the use of the resolver;

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executing rectangular-wave control over the motor using  
the detected rotation angle;  
executing zero learning for learning a deviation between an  
origin of an actual rotation angle of the rotor and an  
origin of the detected rotation angle of the rotor; 5  
correcting the detected rotation angle of the rotor on the  
basis of a result of the zero learning; and  
executing avoidance control for avoiding a rapid variation  
in output of the motor when the zero learning has not  
been completed yet, wherein: 10  
an estimated torque of the motor is calculated using the  
detected rotation angle of the rotor and then feedback  
control is executed over the motor on the basis of a  
deviation between the estimated torque and a command  
torque of the motor when the rectangular-wave control is 15  
executed; and  
in the avoidance control, a rate of change in the command  
torque is limited to below a predetermined value.

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